SAM-TDR-62-139

A DIGITAL READOUT TECHNIC APPLICABLE TO LABORATORY AND AEROSPACE MEDICAL MONITORING OF PHYSIOLOGIC DATA

TECHNICAL DOCUMENTARY REPORT NO. SAM-TDR-62-139

February 1963

USAF School of Aerospace Medicine
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas

Task No. 793002

FOREWORD

This report was prepared by the following personnel in the Department of Bioastronautics:

ODO SIAHAYA, Airman Second Class, USAF
ALAN R. KAHN, Captain, USAF, MC
RAY W. WARE, Captain, USAF, MC

The authors are grateful for the technical assistance of Airman Third Class Merrill B. Kardon, Airman Third Class Allen C. Harris, and Airman Second Class James G. Martin.

ABSTRACT

This report describes a technic for digital readout of systolic and diastolic blood pressure, heart rate, and respiratory minute volume, applicable to wire telemetry in the laboratory as well as wireless telemetry from aerospace vehicles. General description of the technic and specific construction details are given.

This technical documentary report has been reviewed and is approved.

Robert B. Payne
ROBERT B. PAYNE
Colonel, USAF, MSC
Chief, Operations Division

A DIGITAL READOUT TECHNIC APPLICABLE TO LABORATORY AND AEROSPACE MEDICAL MONITORING OF PHYSIOLOGIC DATA

1. INTRODUCTION

Experience in continuous biomedical monitoring, both in the laboratory and in high-performance jet aircraft at the USAF School of Aerospace Medicine, has emphasized the desirability of digital technics of readout and recording of such data. The advantages are: (1) instant access of biomedical information in a form familiar to the medical monitor; (2) considerable saving of man-hours otherwise necessary for data reduction; (3) availability of biomedical data to digital computer equipment without further translation.

This report will describe our technic for digital readout of systolic and diastolic blood pressure, heart rate, and respiratory minute volume, and other parameters if desired. In addition to a general description of the technic, specific construction details will be given.

2. SUMMARY

This report describes a technic for digital readout of systolic and diastolic blood pressure, heart rate, and respiratory minute volume, applicable to wire telemetry in the laboratory as well as to wireless telemetry from aerospace vehicles. Indirect blood pressure is derived in an analog fashion by measuring cuff pressure simultaneously with the occurrence of Korotkov sounds and is then converted to digital information. Heart rate is obtained from the QRS complex of the ECG which, after passing through wave-shape recognition and noise-rejection circuitry, is totalized by a digital counter. Respiratory minute volume is also obtained in an analog fashion by means of a linearized thermistor or thermocouple-type transducer in the oxygen-supply line to the pilot. A voltage-to-frequency converter followed by a digital counter converts the analog signals to digital information and integrates to give respiratory minute volume. A programmer commands recording of the digital data in a predetermined sequence once each minute.

3. GENERAL DISCUSSION

General description

After telemetry, analog-voltage information from the various physiologic transducers is presented through signal modifying and analog-to-digital conversion apparatus for readout and recording (fig. 1). Thus, it is unnecessary to encumber the subject or aerospace vehicle with digital conversion equipment. Detailed description of the function of the components of the system has been given elsewhere (1).

Individual description of the different parameters

Blood pressure. Digital readout of indirect blood pressure is derived from cuff pressure and Korotkov sound signals supplied by a blood pressure apparatus previously described (2). Korotkov sound energy is analyzed at two harmonically unrelated frequencies selected for maximum discrimination against artifact due to ambient noise and motion of the subject; thus, recognition of muffling of Korotkov sound is allowed as a distinct end point of diastolic pressure. Center frequencies of sharply tuned audio filters (fig. 2) in our apparatus are set at 40 cps and 100 cps, or higher (2). The low- and high-frequency, filtered Korotkov signals are each detected and, after shaping to rectangular pulses, are presented to an "and"

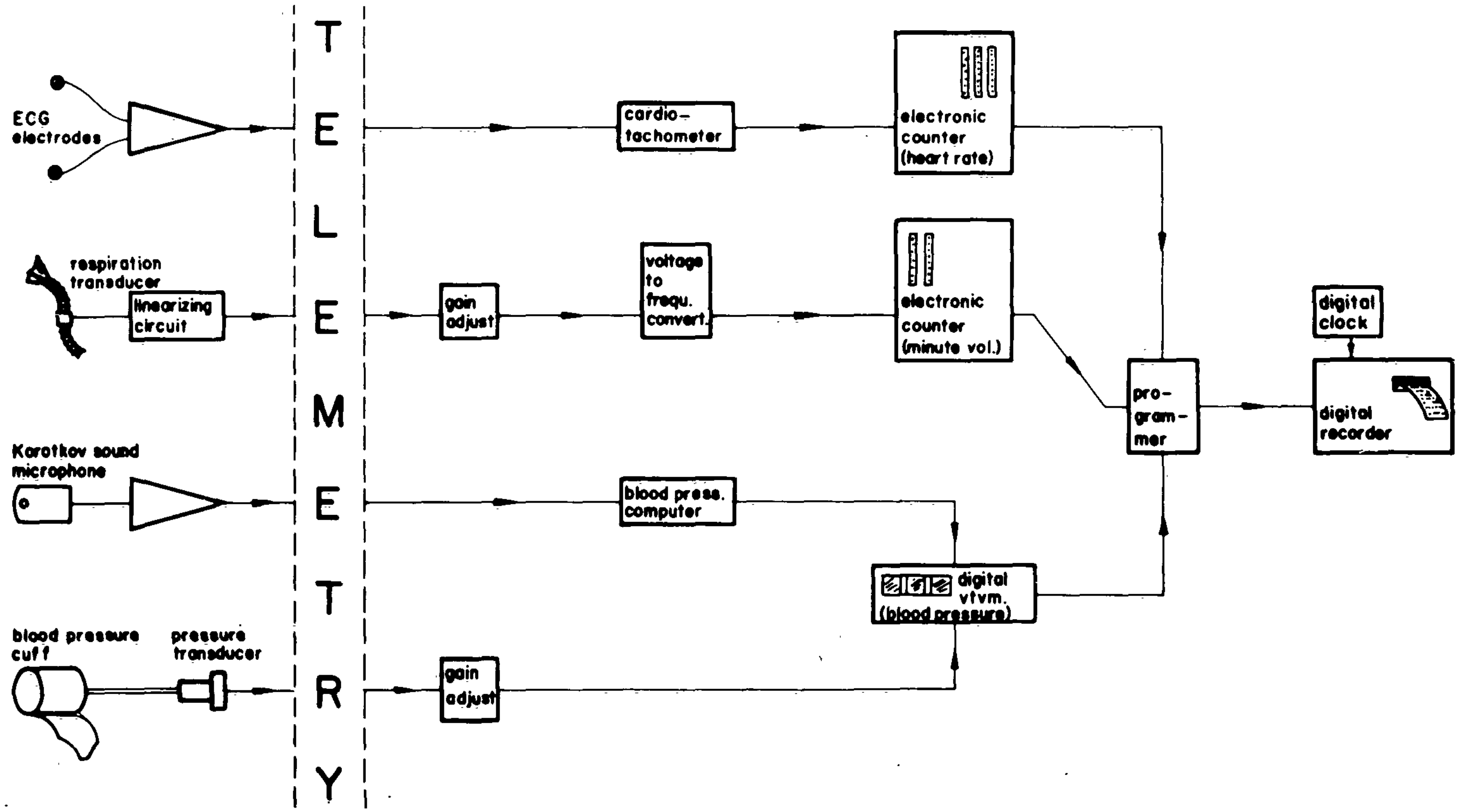


FIGURE 1

Block diagram.

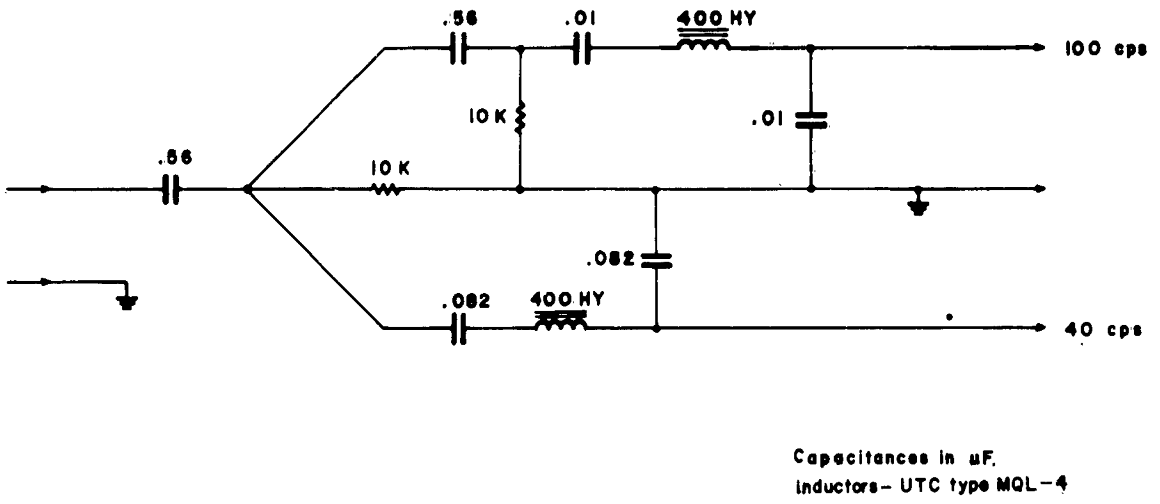


FIGURE 2

Schematic of two-channel Korotkov sound filter.

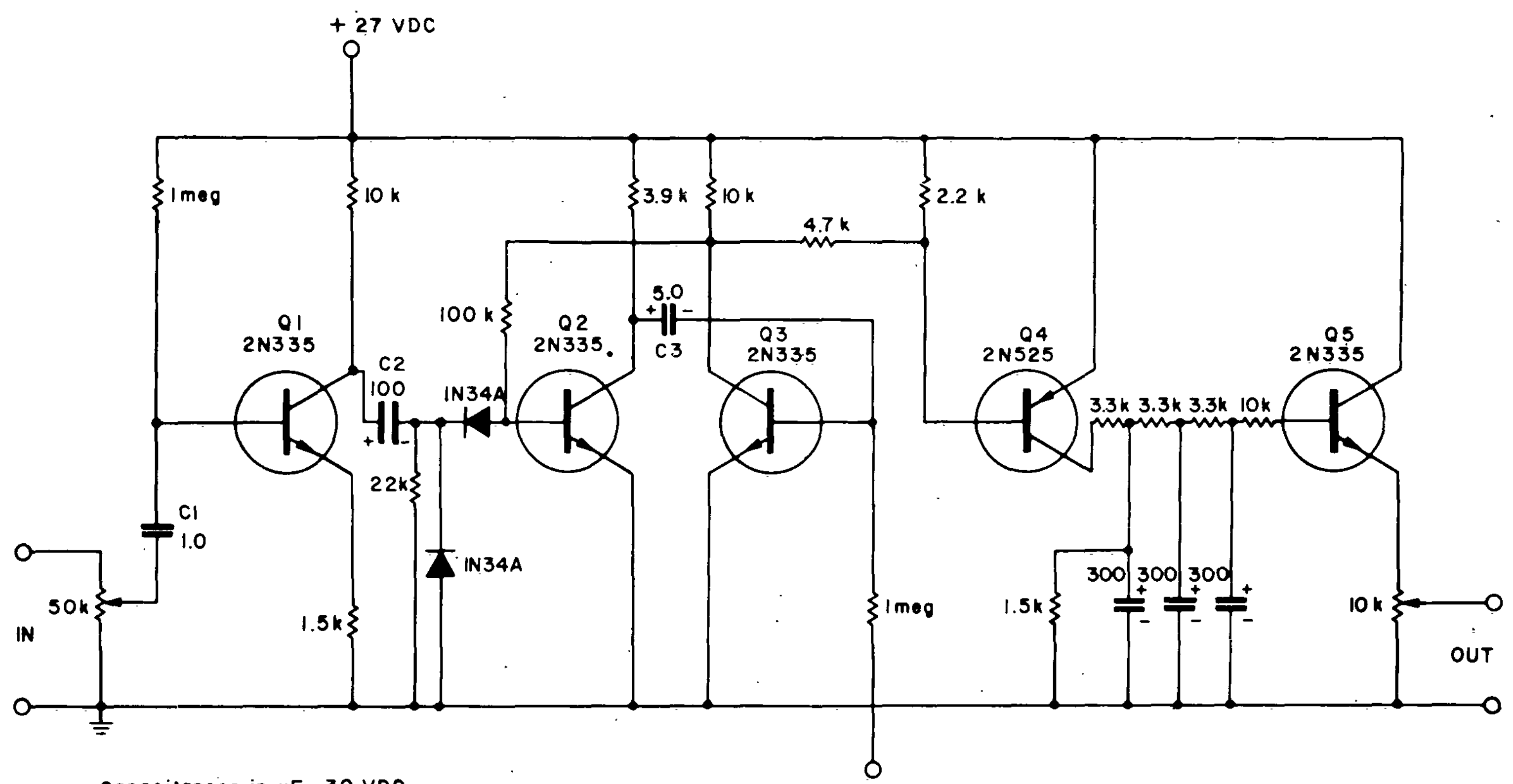
circuit which, when triggered simultaneously by 40 cps and 100 cps energy input, produces a 27-volt pulse of 200 msec. duration. In this manner, sounds from the microphone are instantly examined for amplitude, envelope configuration, and frequency content. Extraneous sounds and phase 4 Korotkov sounds are rejected, and a valid sound is indicated by a rectangular pulse which commands cuff pressure to be displayed and printed out at the moment of each Korotkov sound. The first and last pressure in each train of pressure values printed correspond to systolic and diastolic blood pressure, respectively.

Heart rate. Heart rate information obtained by motion-artifact-free electrocardiograph technics (3) is applied in the form of ECG voltage to special cardiotachometer circuitry (4) (fig. 3) used to identify and respond to the QRS complex of the ECG while ignoring P and T waves and artifact such as hum. As each heart beat occurs, a pulse is supplied to an electronic counter which totalizes heart beats during each minute.

Respiration. A signal voltage proportional to inspiratory flow is integrated by a voltage-to-frequency converter and an electronic counter gated for one minute. The respiratory signal voltage and the sensitivity of the above-mentioned integrator are scaled so that the counter reads respiratory flow directly in liters.[1]

Programmer. A programmer causes the digital recorder to print the different physiologic values in a predetermined sequence once each minute. During the first 30 seconds of each minute it commands blood pressure to be printed as described. During the next half minute, it commands the remaining digital counters (heart rate, respiration, and environmental or additional physiologic parameters, if desired) to print out and reset sequentially. The recording program is shown in figure 4. A time signal is printed simultaneously with each physiologic datum, producing a record as shown in figure 5. Cuff-pressure readings corresponding to Korotkov sounds between systolic and diastolic pressure are purposely not suppressed, because recognition of artifact is

[1]Respiratory frequency, if desired as an additional parameter, could be obtained and displayed in a manner similar to that described for heart rate. Interpretation of respiratory values would be aided by knowledge of ambient pressure, which could also be displayed digitally by slight modification of this technic.



Capacitances in μF, 30 VDC.
C3 chosen for 200 msec. pulse
at Q3 collector.

FIGURE 3

Schematic of cardiotachometer.

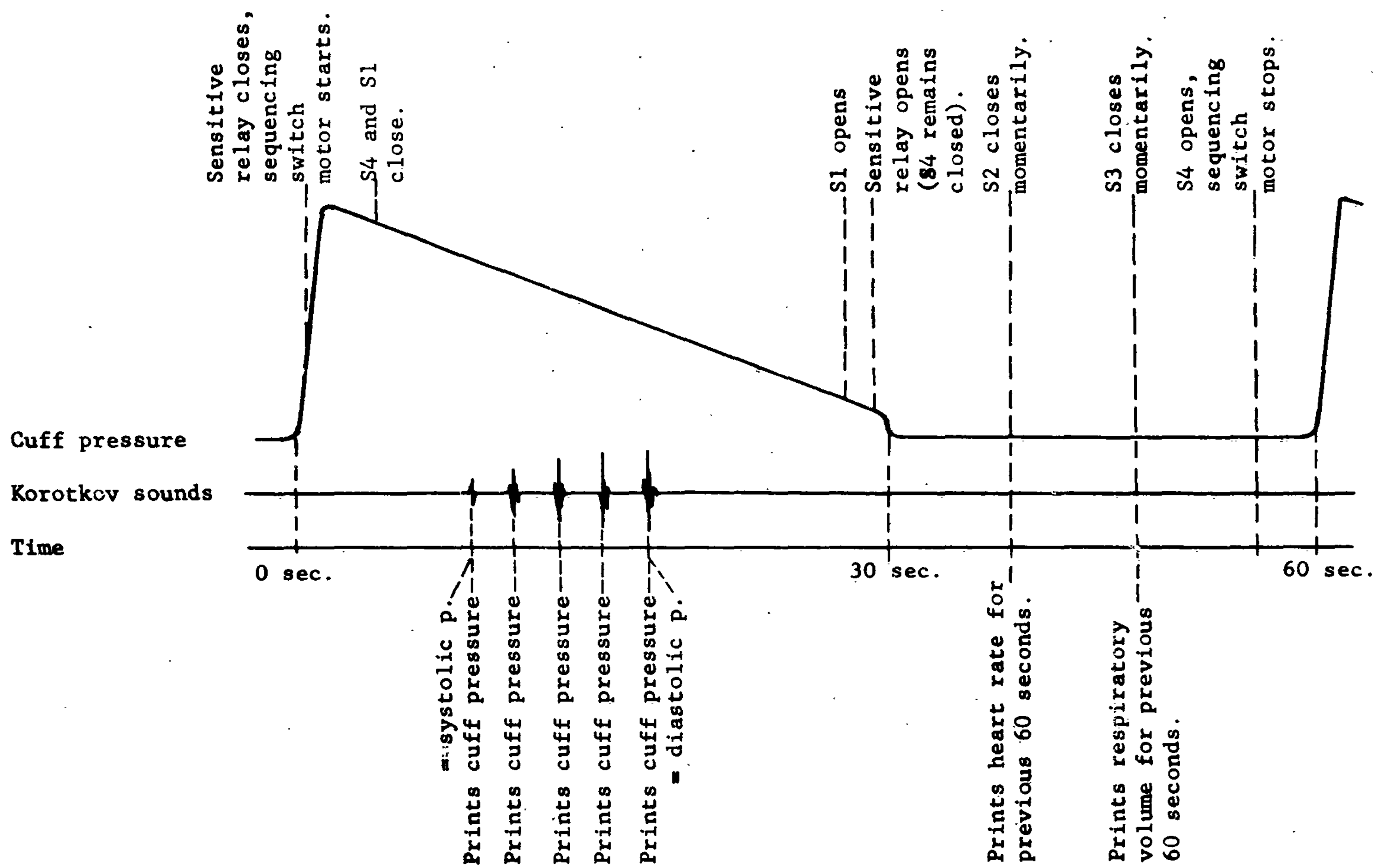


FIGURE 4

Diagram of the printing program of digital recorder.

Time Hrs.Min.Sec.		
163121	11	.... Respiratory Volume
163118	069	.... Heart Rate
163112	081	.... Diastolic Blood Pressure
163111	089	
163110	095	
163110	102	
163109	109	
163108	117	
163107	125	.... Systolic Blood Pressure
163022	09	.... Respiratory Volume
163018	067	.... Heart Rate
163012	084	.... Diastolic Blood Pressure
163011	092	
163010	099	
163009	105	
163008	113	
163008	120	.... Systolic Blood Pressure
162922	09	.... Respiratory Volume
162919	069	.... Heart Rate
162913	082	.... Diastolic Blood Pressure
162912	089	
162911	096	
162910	103	
162909	110	
162908	118	.... Systolic Blood Pressure

FIGURE 5

Sample of digital record obtained from subject in flight.

considerably enhanced when the entire rhythmic train of Korotkov sounds is represented by the series of cuff-pressure and time signals.

4. DETAILED NOTES ON CONSTRUCTION

General

The programmer to be described in detail was specifically designed to control particular digital equipment available to us when the work was undertaken.[2] Obviously, certain modifications would be necessary to utilize other digital equipment. The proper modifications can be determined by studying the pertinent technical manuals. The programmer consists of the following functional units: (1) cycle

[2]Hewlett-Packard automatic digital voltmeter model 405CR, Hewlett-Packard electronic counters model 521C, Hewlett-Packard digital recorder model 560A, Dymec voltage-to-frequency converter model DY-2210.

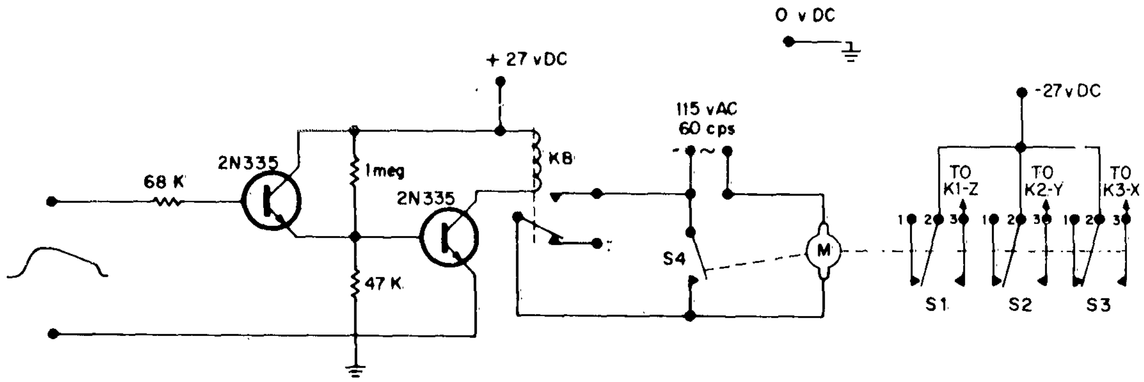


FIGURE 6a

Cycle initiation circuit and sequencing switches.

initiation circuitry; (2) sequencing switches; (3) programming relays.

Cycle initiation circuitry

Since the cuff inflation cycle is an accurately timed event in our blood pressure apparatus, the output voltage of the cuff-pressure telemetry channel is used to initiate the readout cycle once per minute. In this way, the readout cycle is always slaved to that of the remote sensing apparatus. The cuff-pressure discriminator output is coupled through an emitter-follower stage to a transistor with a sensitive relay[3] as its collector load (fig. 6a). The cuff-pressure discriminator voltage is divided so that the sensitive relay operates at approximately one-half the maximum cuff pressure and drops out approximately 25 seconds later as the cuff pressure falls toward zero. As the sensitive relay closes, it starts the motor-driven, cam-operated sequencing switches (S-1 through S-4). One of these switches (S-4) is used to continue motor operation until the sequencing cams complete one revolution after the cuff pressure has dropped to zero. In other words, the sequencing switch motor is connected to run when either the sensitive relay or S-4 is closed. After a few seconds, S-4 remains closed until one revolution of the sequencing switch cams is completed. To insure that the sequencing switch cycle will remain slaved to the one-minute inflation cycle, the sequencing switch cams must complete one revolution in less than 60 seconds.[4] The remaining time-operated switches are individually adjusted for proper sequencing of the programming relays as shown in figure 3. The programming relays (K-1, K-2, and K-3)[5] are operated in sequence by S-1, S-2, and S-3, respectively, and control the connection of the digital printer to the various analog-to-digital converter devices as follows: K-1 connects the digital voltmeter; K-2 connects the heart rate counter; K-3 connects the respiratory minute volume counter (figs. 6b and 6c). Additional relays are needed to accommodate additional parameters.

Modification of digital equipment

If equipment is to be purchased specifically for this application, simpler, less expensive digital equipment may be used in view of the following considerations:

[3]Model SVIC 14,000D, 26.5 VDC, coil resistance 14,000 ohms, made by Advance Electric and Relay Co. Other relays could be used by redesigning the transistor amplifier.

[4]Sequencing switch device made by Industrial Timer Corporation, Newark, N.J., Model MC-4, 115 VAC, 60 cycles, 1,000 watts. If more than 3 parameters are to be monitored, more than 4 cam-switches will be required. These devices can be ordered in kit form and assembled with more or less cam-switches as desired. Use optional gears to produce 1 revolution/48 sec. (1.2 r.p.m. approximately).

[5]Style PM Relay UN312585-005, 26.5 VDC, −55° C. Cat. No. R35PGCA, 6-pole double throw (5 poles utilized). The exact type of relay is not critical.

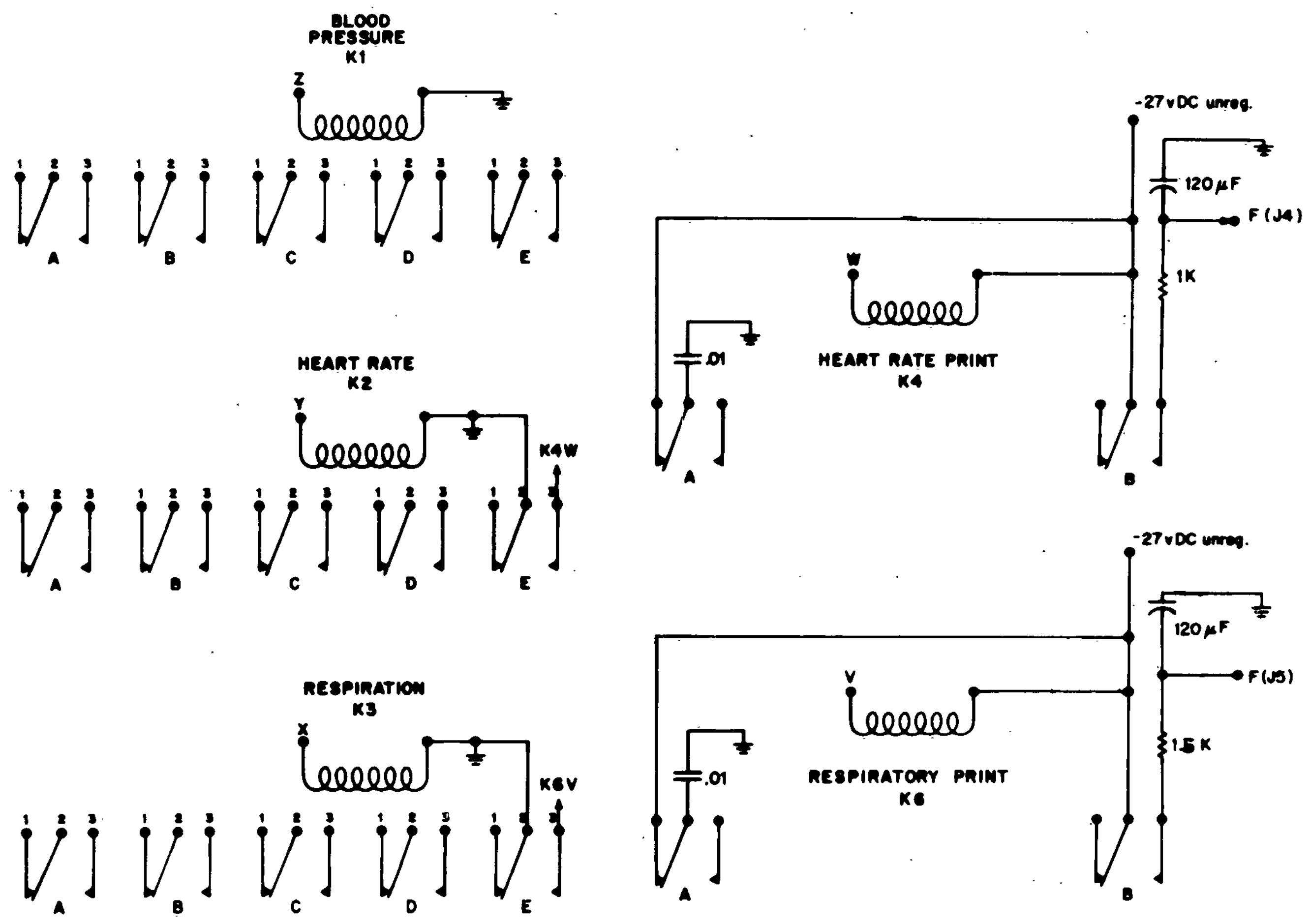


FIGURE 6b

Programming relays.

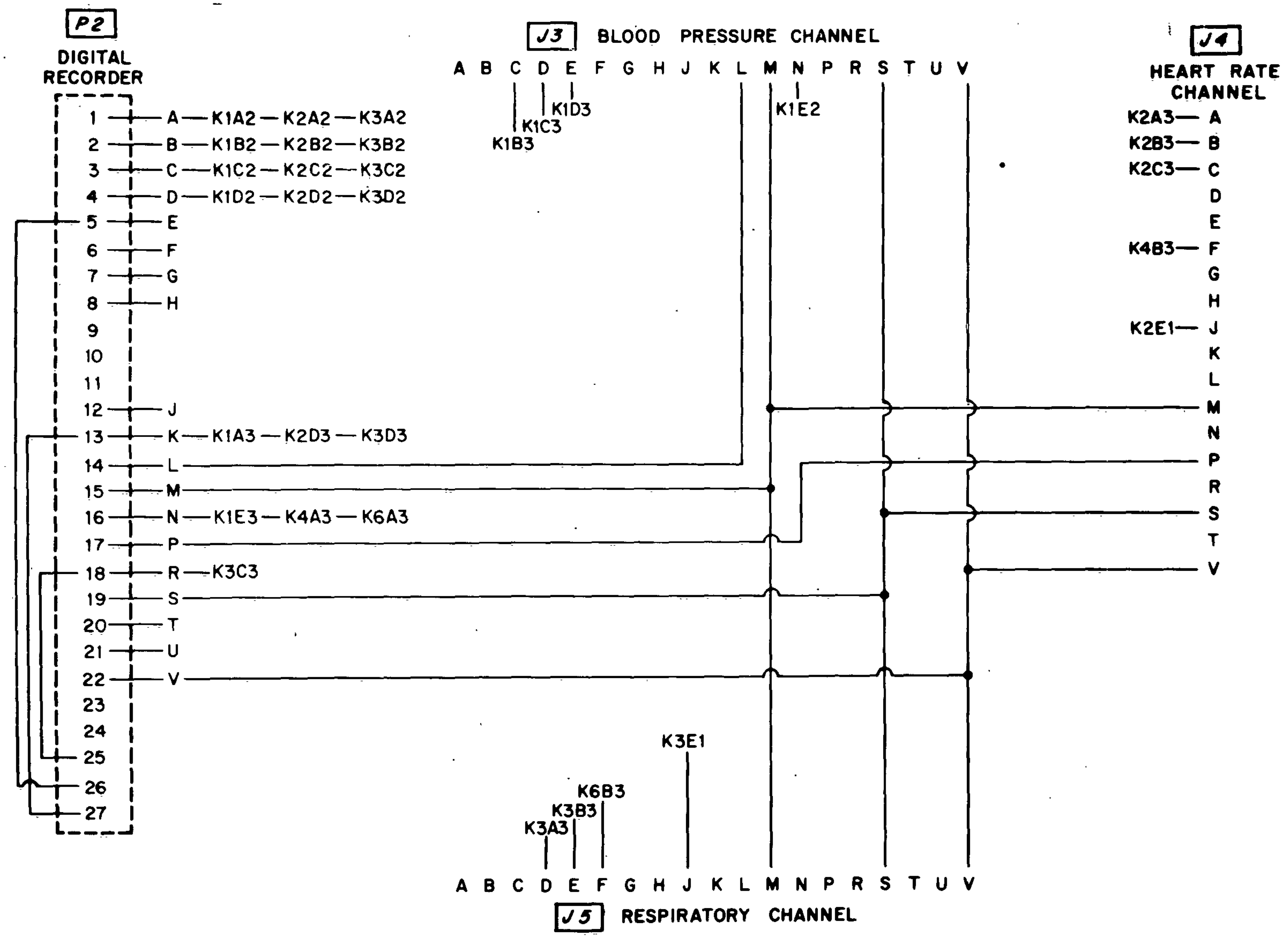


FIGURE 6c

Wiring diagram of programmer.

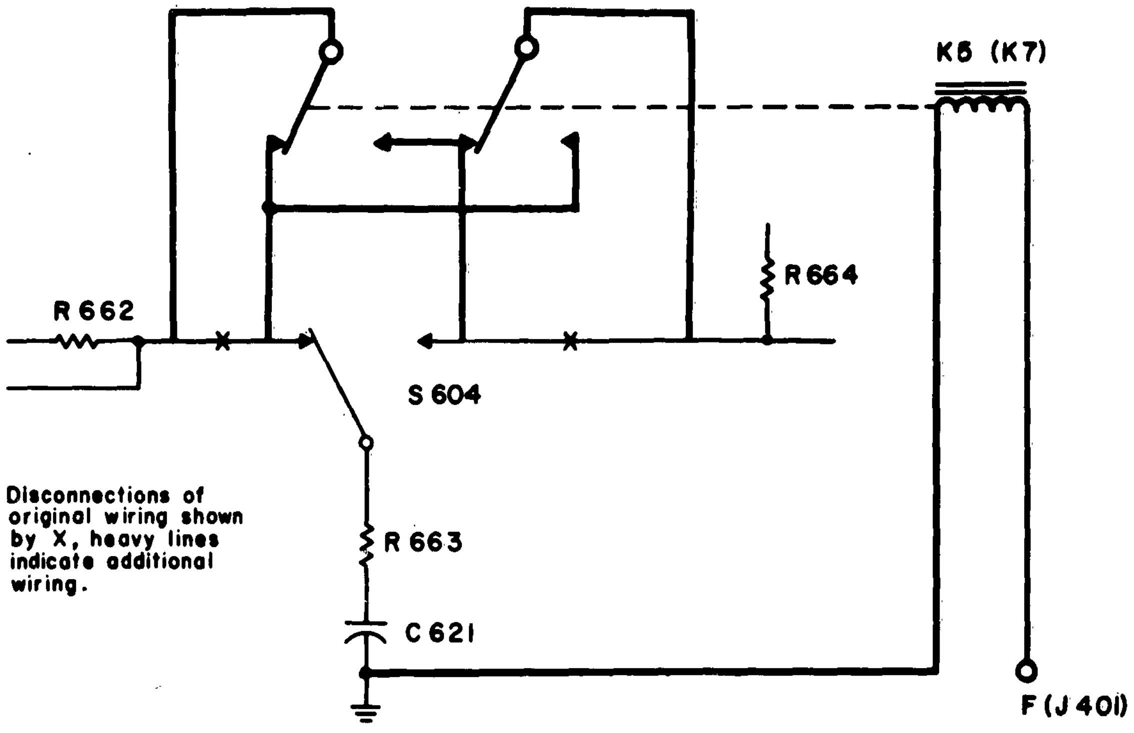


FIGURE 7

Diagram of reset relay installation for counters.

1. The digital voltmeter need have only one range to accommodate 0-2.50 volts. Since analog voltage must be numerically equal to the cuff pressure, no range adjustment is desirable.

2. The heart rate counter needs only three digits and need not be capable of fast count.

3. The voltage-to-frequency converter needs only one range, and respiratory volume counter requires display of only two digits, although additional low-order counting decades will probably be necessary (depending on the frequency range of the voltage-to-frequency converter) in order to achieve proper scaling.

4. No timing circuits are required in either counter since gating is accomplished by programming relays. To minimize inaccuracy due to dead time of counters while readout and reset are effected, cam switches S-2 and S-3 are adjusted for one-half second (or less) dwell time.

The digital recorder must, of course, be electrically compatible with the above-mentioned digital equipment and should be capable of printing faster than the maximum expected heart rate for the sake of accuracy in blood pressure recording.

After the programmer is wired according to figure 6c, the following step-by-step modifications and connection procedures are applicable to the specific equipment used in this project:

1. *Modification of counters for remote reset.* Double-pole, double-throw relays, K-5 and K-7, are installed inside the case of the heart rate and respiration counters, respectively. After the counters are wired as shown in figure 7, reset can be accomplished either by the manual reset buttons or remotely by the programmer. The reset relays, K-5 and K-7, are activated by -27 VDC from relays K-4 and K-6, respectively. RC networks (1,000 ohms and 120 μf. at K4B3 and K6B3) delay reset of

the two counters until adequate time for printout has elapsed (fig. 6b).

2. *Modifications of counters for remote gate control.* Although an external gate-control jack is provided by the manufacturer (J603 in fig. 4-11 of the H. P. Electronic Counter, Model 521C Manual), one may make a direct connection through one of the unused wires in the interconnecting cable so that all connections can be made from the rear. This is done by connecting a wire between the normally open terminal of switch S-602 and the unused pin J of jack J-401. When the corresponding wire is grounded inside the programmer (figs. 6b and 6c), the counter will count until the associated relay, K-2 or K-3, is activated, thus allowing the information to be printed.

3. *Heart rate counter.* Deactivate the *thousands* and *ten thousands* decades by disconnecting the +300 VDC power at the plug-in units.

4. *Respiratory minute volume counter.* Mask, but do not inactivate the *units, tens,* and *hundreds* decades.

5. *Modification of interconnecting cables.* Cables to connect counters and digital voltmeter to the digital recorder may be obtained from the manufacturer. Four of them are needed in our device; three are the input cables to the programmer and the fourth is the cable connecting the programmer to the digital recorder. The three input cables do not require further modification if mating connectors are used on the programmer. To locate the blank spaces correctly to produce a recording pattern as shown in figure 5, one must modify the programmer output cable connector which plugs into jack J 1 of the H.P. digital recorder, Model 560A, as follows: Disconnect the jumpers from pins 9, 10, and 11, and connect them instead to pins 5, 13, and 18, respectively (fig. 6c of this report and fig. 2-4 of the manual of the recorder).

Blood pressure computer circuit

This device, shown schematically in figure 8, has two input circuits (one for each filter frequency), each consisting of an impedance-matching circuit, an envelope detector circuit, and a one-shot multivibrator circuit. Approximate resistance and capacitance values are shown, since differences in individual transistor characteristics make it necessary to adjust these values experimentally to obtain proper voltages at points indicated. To determine the correct values, the voltages at points A, B, C, and D should be measured with the multivibrator in the unstimulated condition. Voltage at A should be set at 10 $\pm$ 3 volts by adjusting R-1. Voltage at B should be 0 $\pm$ 1 volt (adjust R-2). Voltage at C should be less than 0.5 volt since the transistor at point C is conducting. The voltage at D, which depends on R-2 and the collector to base resistance of the second transistor, should be approximately 26 volts. The value of resistor R-3 in the B-minus circuit determines the duration of the rectangular pulse which should be 250 msec. If it is impossible to obtain this duration by changing the value of R-3, then the 5.0 μf. coupling capacitor should be changed to a different value. It is important that the leakage current of this capacitor be very small. The outputs of both multivibrators are connected to an "and" circuit, which will put out a signal only when triggered simultaneously by both multivibrator circuits. The output of the "and" circuit triggers a final multivibrator, which lends constancy to output pulse duration. The correct duration of the pulse—200 msec.—can be obtained by adjusting the resistor in the B-minus circuit of the output transistor. Again, the voltages at points F and G should be less than 0.5 and approximately 26, respectively.

5. CALIBRATION

Heart rate

Adjust the cardiotachometer input sensitivity control so that the counting rate of the electronic counter is equal to the rate of occurrence of the QRS spikes as monitored on an oscillograph or oscilloscope.[6]

[6]Accuracy of heart rate and respiratory minute volume values is limited to about 1% because the counters are disabled for about 0.5 second each minute to allow readout and reset.

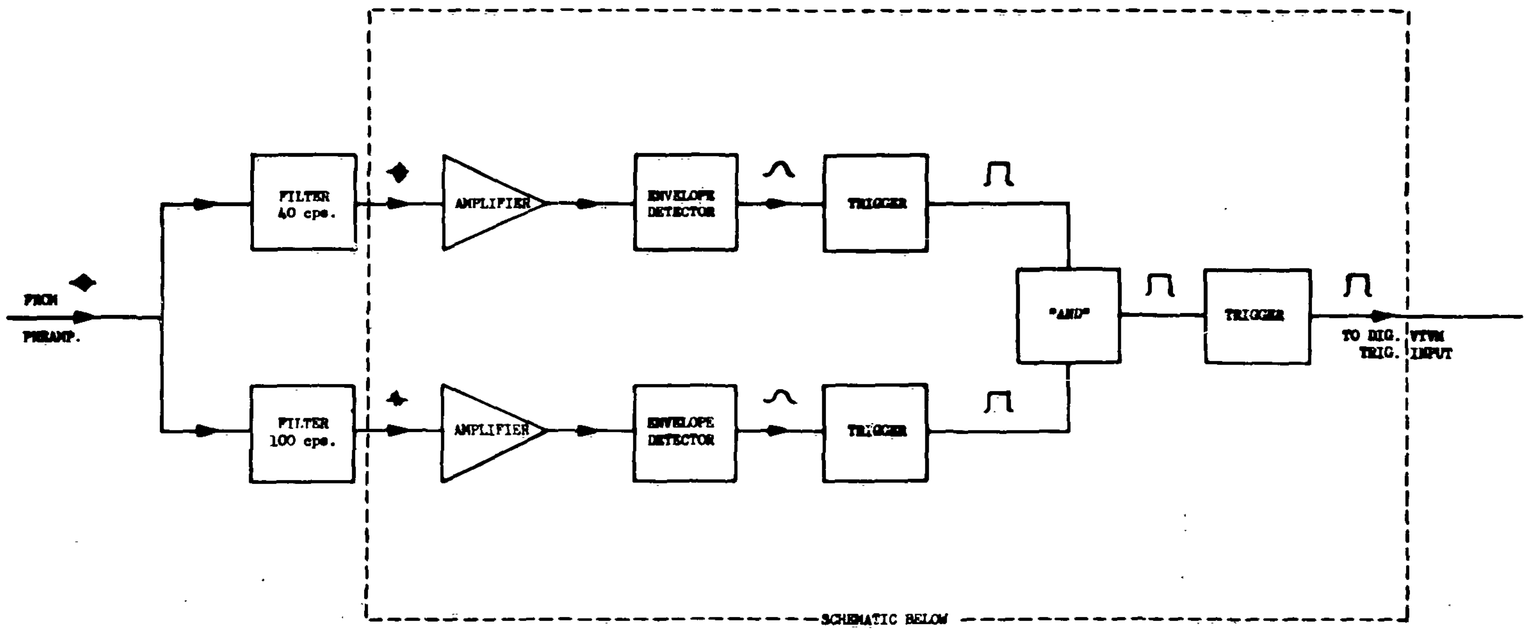
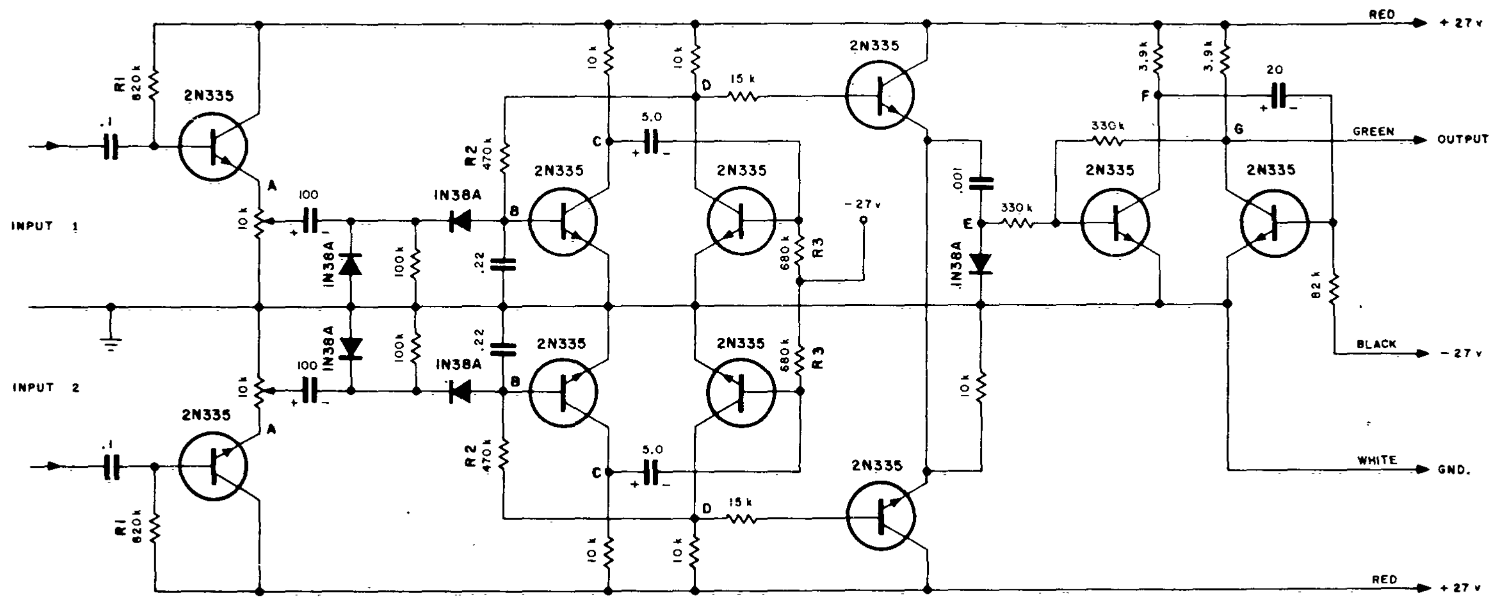


FIGURE 8a

Block diagram of blood pressure sound computer.



NOTE: ALL CAPACITORS ARE IN MICROFARADS

POWER SUPPLY

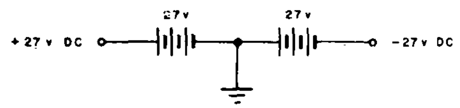


FIGURE 8b

Schematic of blood pressure sound computer.

Respiratory minute volume

Connect a spirometer to the respiratory-flow transducer so that a measured volume of air can be delivered through the flow transducer. By adjusting a voltage divider at the input of the analog-to-digital converter, the counter can be made to read the same number as the volume of air in liters delivered by the spirometer. In our device, this number appears on the *thousands* and *ten thousands* decades, and the remaining ones are not connected to the printer. If flow transducer accuracy warrants, the *hundreds* decade may also be connected to the printer in order to display respiratory volume to the nearest tenth liter. Linearity check is obtained by blowing the same volume of air through the transducer at different rates. The respiratory flow analog voltage applied to the integrator should be linearly related to flow and suppressed to zero at zero flow.

Cuff pressure

Switch the digital voltmeter to the sampling mode so that the output of the pressure transducer will be displayed continuously. By adjusting the voltage divider and a zero suppressor, if necessary, at the input of the digital voltmeter, the latter can be made to read numerically the same as a directly connected calibrating manometer. Switch back to external trigger mode.

Accuracy of the digital conversion is much greater than that of the methods used to sense the physiologic data. To obtain maximum accuracy, the dwell time of switches S-2 and S-3 and the time constant of relays K-5 and K-7 (120 μf. capacitors) should not exceed 0.5 second total.

REFERENCES

1. Kahn, A. R., R. W. Ware, and O. Siahaya. Digital read-out for aerospace biomedical monitoring. Amer. J. Med. Electronics. (In press)

2. Ware, R. W., and A. R. Kahn. Automatic blood pressure determination in flight. J. Appl. Physiol. (In press)

3. Roman, J. A., and L. E. Lamb. Electrocardiography in flight. Aerospace Med. 33:527-544 (1962).

4. Kahn, A. R. Reliable miniaturized cardiotachometers for multiple applications. J. Appl. Physiol. 16:902-905 (1961).

USAF School of Aerospace Medicine, Brooks AF Base, Tex.

SAM-TDR-62-139. A DIGITAL READOUT TECHNIC APPLICABLE TO LABORATORY AND AEROSPACE MEDICAL MONITORING OF PHYSIOLOGIC DATA. Feb. 63, 14 pp. incl. illus., 4 refs.

Unclassified Report

This report describes a technic for digital readout of systolic and diastolic blood pressure, heart rate, and respiratory minute volume, applicable to wire telemetry in the laboratory as well as wireless telemetry from aerospace vehicles. General description of the technic and specific construction details are given.

1. Bioinstrumentation
2. Space medicine

I. AFSC Task 793002
II. Siahaya, O., Kahn, A. R., Ware, R. W.
III. In ASTIA collection

USAF School of Aerospace Medicine, Brooks AF Base, Tex.

SAM-TDR-62-139. A DIGITAL READOUT TECHNIC APPLICABLE TO LABORATORY AND AEROSPACE MEDICAL MONITORING OF PHYSIOLOGIC DATA. Feb. 63, 14 pp. incl. illus., 4 refs.

Unclassified Report

This report describes a technic for digital readout of systolic and diastolic blood pressure, heart rate, and respiratory minute volume, applicable to wire telemetry in the laboratory as well as wireless telemetry from aerospace vehicles. General description of the technic and specific construction details are given.

1. Bioinstrumentation
2. Space medicine

I. AFSC Task 793002
II. Siahaya, O., Kahn, A. R., Ware, R. W.
III. In ASTIA collection

USAF School of Aerospace Medicine, Brooks AF Base, Tex.

SAM-TDR-62-139. A DIGITAL READOUT TECHNIC APPLICABLE TO LABORATORY AND AEROSPACE MEDICAL MONITORING OF PHYSIOLOGIC DATA. Feb. 63, 14 pp. incl. illus., 4 refs.

Unclassified Report

This report describes a technic for digital readout of systolic and diastolic blood pressure, heart rate, and respiratory minute volume, applicable to wire telemetry in the laboratory as well as wireless telemetry from aerospace vehicles. General description of the technic and specific construction details are given.

1. Bioinstrumentation
2. Space medicine

I. AFSC Task 793002
II. Siahaya, O., Kahn, A. R., Ware, R. W.
III. In ASTIA collection

USAF School of Aerospace Medicine, Brooks AF Base, Tex.

SAM-TDR-62-139. A DIGITAL READOUT TECHNIC APPLICABLE TO LABORATORY AND AEROSPACE MEDICAL MONITORING OF PHYSIOLOGIC DATA. Feb. 63, 14 pp. incl. illus., 4 refs.

Unclassified Report

This report describes a technic for digital readout of systolic and diastolic blood pressure, heart rate, and respiratory minute volume, applicable to wire telemetry in the laboratory as well as wireless telemetry from aerospace vehicles. General description of the technic and specific construction details are given.

1. Bioinstrumentation
2. Space medicine

I. AFSC Task 793002
II. Siahaya, O., Kahn, A. R., Ware, R. W.
III. In ASTIA collection